Journal of Forestry Research (2013) 24(4): 755−758
DOI 10.1007/s11676-013-0370-9

ORIGINAL PAPER

Traditional mule logging method in Hyrcanian Forest: a study of the impact on forest stand and soil

Meghdad Jourgholami • Baris Majnounian

Received: 2012-03-24; Accepted: 2012-09-29

Abstract: We inventoried plant regeneration and soil compaction along mule trails to evaluate damage to forest stands and regeneration following mule hauling before and after operations in Kheyrud Forest in the Hyrcanian Forest in northern Iran. About 22% of regenerating plants on mule trails were damaged following mule logging, and damage to trees was observed. In harvested units after timber extraction, 4.3% of the total area (12 ha) was covered with mule trails. Mule passes and slope gradient, and twofold interactions between mule passes × slope gradient had no significant effect on soil bulk density ($p < 0.05$). Mule logging had a statistically significant effect on soil bulk density along the mule trails before and after mule passes. Soil bulk density increased significantly as mule passes increased in number. The degree and level of compaction did not differ with trail slope. With respect to damage to residual stands and seedlings, soil compaction and disturbance to soil, traditional mule logging is the preferred skidding method in the steep terrain conditions in the Hyrcanian Forest in northern Iran.

Keywords: Mule logging; stand damage; seedling; soil compaction

Introduction

For many years, animals were only source of power for log skidding and the primary power for hauling in timber harvesting. Before the invention of logging machines and trucks, animal power was the main source of land transport throughout the world (Wackerman et al. 1966; Oskarshamn 1983). Log extraction with draught animals continues to be an economically attractive choice in many areas, sometimes even in industrialized countries (Rodriguez and Fellow 1986; Wang 1997; Akay 2005; Sessions et al. 2007). Compared with mechanical skidding, the use of draught animals can reduce soil disturbance, soil compaction and damage to residual trees (Rodriguez and Fellow 1986; Wang 1997; Shrestha and Lanford 2005; Jourgholami et al. 2008). Ghaffariyan (2002) and Ghaffariyan et al. (2009) showed, however, that soil compaction and damage to residual trees and seedlings were higher with animal skidding when compared to mechanical skidding in the northern forests of Iran.

After timber extraction using mules and horses, only 3% of the surface area was disturbed, 22% had slight rutting and disturbance, and 75% had no disturbance (Shrestha 2002). Ghaffariyan (2009) concluded that soil disturbance was observed on 5.7% of the harvest area, and soil compaction in the skid trails increased by over 14%. Seedling numbers declined from 545 to 377, meaning that 31% of seedlings in skid trails were destroyed by mule logging. Thompson and Sturos (1984) reported that skidding with mules and horses caused no more damage to soils than did machine skidding. McGonagil (1979) studied mule skidding in Alabama and found little damage to skid routes, disturbance of the upper 5 cm layer of soil, and damage to some trees. Wang (1997) compared animal logging with mechanical timber extraction in Heilongjiang, China and reported that disturbance by machine skidding was slightly more severe than animal skidding in spite of the heterogeneity of soil types. He also concluded that direct damage caused by machine skidding was much more severe than from animal skidding due to the large size, high power, and low flexibility of machinery. Horse and mule loggers in Alabama, USA work mostly in non-industrial privately owned forests (Toms et al. 2001). The typical animal logging operation consists of three people, two animals and a side-loading truck. Most animal loggers find their niche in Alabama's logging industry by working on small tracts with low timber volumes and harvests that use selective thinning (Toms et al. 2001).

Hyrcanian (Caspian) Forest in northern Iran has rich biological diversity with endemic and endangered species. The use of mechanical skidding was widely accepted but this tended to cause greater environmental impacts. This traditional mule hauling system was established in the Hyrcanian Forest region because the forest management plan and the forest road network were undeveloped. Recently, due to increasing environmental awareness, focus on environmentally sound timber extraction and

Meghdad Jourgholami (✉) • Baris Majnounian
Department of Forestry and Forest Economics, Faculty of Natural Resources, University of Tehran, P. O. Box 31585-4314, Karaj, Iran.
E-mail: mjgholami@ut.ac.ir

Corresponding editor: Yu Lei

small-scale tree harvesting has increased. Thus, mule logging has increased in the Hyrcanian Forest region. Ghaffariyan et al. (2009) studied the effect of mule skidding on forest soils of the Kheyrud Forest, and concluded that soil bulk density increase by 13.8% in skid trails after 28 passes. Jamshidi et al. (2008) measured the changes in bulk density in the top 10 cm of soil following machine and animal skidding in the Hyrcanian Forest. They found that average soil bulk density in the tracks of machine skid trails was significantly greater than the soil density outside the tracks, but the increase in bulk density was not significant on animal skid trails. Our study aimed to quantify soil disturbances, bulk density changes, and changes in plant regeneration following mule logging operations.

Materials and methods

Study Sites

The research was carried out in compartments 219 and 223 in Namkhaneh District within Kheyrud Educational and Research Forest in the Hyrcanian Forest (51°32′31″–51°35′38″ N, 36°37′25″–36°34′30″ E). Elevations ranged from 1,060–1,235 m a.s.l. and the logged forest was on a southwesterly aspect. The slopes on sampled sites ranged from 10%–65% with an average of 35%. Average rainfall ranged from 1,420–1,530 mm·a^{-1}, with heaviest precipitation during summer and fall. Our study area was dominated by natural forests of native mixed deciduous tree species, including *Fagus orientalis* Lipsky, *Carpinus betulus* L., *Acer velutinum* Boiss. and *Alnus subcordata*. The management prescription aimed for a mixed species, un-even aged, tall forest with both single and group selective cutting regimes. Trees to be removed were felled, limbed and topped motor-manually. Felled trees were bucked and processed with chainsaws into logs, sawn-lumber and pulpwood. Logs of 5–15 m lengths were extracted by wheeled cable skidders to the roadside landings and fuelwood was extracted by mules. The field study was conducted from August to September 2010.

Residual damage to regeneration along trails

Residual damage to vegetation along mule logging trails was estimated by inventory and classification of seedlings and saplings in three height classes (Ghaffariyan et al. 2009): seedling (0–0.5 m), small sapling (0.5–2 m) and sapling (2–6 m). After mule hauling, the seedlings in mule trails were inventoried and categorized by wound type such as health, wound (damage to most of the stem), broken top (damage to the sapling crown), crushed (both stem and crown of sapling completely crushed), and grazed by mules (Ghaffariyan et al. 2009). The lengths of winching strips differed, but the width of the trails was kept constant at 1.6 m (0.8 m on each side).

Experimental design to measure soil compaction

We demarcated 12 sampling transects at various slope gradients along the mule trails to sample soil bulk density. Prior to mule logging, we sampled four slope gradients in mule trails, each with three replications in disturbed areas at 1–10 cm soil depth. Levels of compaction were sampled for increasing intensities of mule traffic: 0 (undisturbed), 1, 5, 8, 10, 15, 20, 25, and 30 mule passes. We defined a “mule pass” as one return trip along a given trail. Four categories of slope gradient of mule trails were assigned: 0 (flat trail), -10% (uphill hauling direction), 10 and 20% (downhill hauling direction). Also, prior to any mule passes and after 20 passes, the soil bulk density was measured for each of the four slope gradient categories (0, -10, 10, and 20%) at 3 soil profile depths (0–10 cm, 10–20 cm, 20–30 cm) in ruts (B) and at uncompacted sample points adjacent to mule trails (C). The soil sample cores were obtained using a thin walled steel cylinder, 40 mm long and 56 mm in diameter, driven into the soil by a hammer-driven device. After mule skidding, the steel cylinder was removed from the soil with minimal disturbance to the contents and soil cores were trimmed flush with the cylinder end and extruded into a plastic bag for transport to the laboratory. Samples were weighed immediately after collecting and also after oven drying at 105°C for 24 h to determine the water content and bulk density.

The experimental design was a factorial arrangement of treatments conducted in a completely randomized design. Data were evaluated for normality before analyses. We also applied general linear modeling (GLM) related to bulk density and rut depth to mule passes, slope gradient, depth, and soil moisture. Post-hoc comparison of means was performed using Duncan’s multiple design at 95% confidence level. Analyses of variance of the test data were conducted in SPSS (release 11.0.0). Treatment effects were considered significant at $p < 0.05$. To determine the impact of slope gradient and number of mule passes on bulk density, a regression approach was used. Soil bulk density before and after skidder operations was compared using independent samples t-tests. One-way ANOVA was performed to identify differences between bulk density values in four slope gradient categories.

Results

Damage to seedlings along mule trails

After mule logging, 913 seedlings were damaged along mule trails, accounting for 22% of all seedlings and saplings in the forest stand. No trees were damaged. Damaged plants were comprised of 75.6 % seedlings, 16.7 % small saplings and 7.7 % saplings (Fig.1).

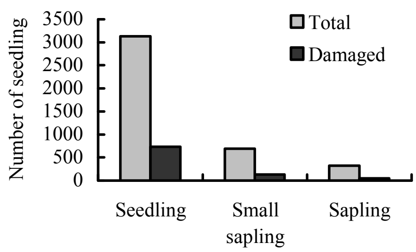

Fig. 1 Total and damaged plants in three classes after mule logging

On average, 22% of seedlings-saplings were damaged by mule skidding. The proportions of damage declined with increasing seedling height class. The proportion of damaged small saplings was 18.8%, declining to 15.3% for saplings. Most damage was suffered by seedlings (height <0.5 m), which occurred at higher densities than the other two classes (Fig. 2).

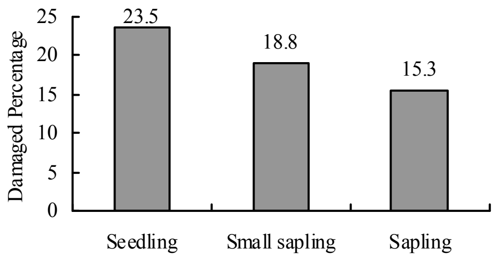

Fig. 2 Percent damage in three seedling classes due to mule hauling

Most damage was due to crushing of seedlings. Wounded, broken top and grazed seedlings were less common, at 31.4, 8.6 and 3%, respectively. The proportion of crushed seedlings declined with increasing seedling height.Abrasion by skidded timber caused removal of skins and leaves from seedlings/saplings. Small saplings were wounded (49%) and grazed (19%) by mules, while 16.5% of small saplings in the skid trails were crushed or cut off by workers because they hindered movements of mules and created difficulties in carrying timber. This trend was also seen in the sapling class where 52% were wounded and 24% were cut off by workers (Fig. 3).

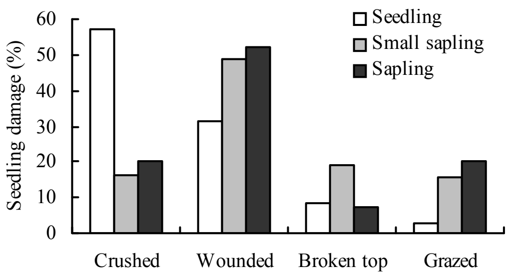

Fig. 3 Percentage of damaged seedlings and saplings in skid trails after mule hauling

Soil compaction

A detailed survey of the harvest area after mule hauling showed that 3.6% of the total area was covered by hauling routes and 0.7% of the total area was covered by timber depots at roadsides. Overall, 4.3% of the total area (12 ha) after mule hauling operation had some degree of disturbance and was compacted. Numbers of mule passes, slope gradient, and interaction between mule passes and slope gradient were all insignificant variables (p<0.05). Mule logging had a statistically significant effect on soil bulk density along the mule trails (Fig. 4a). Soil bulk density increased significantly with increasing numbers of mule passes. The degree of compaction did not differ by trail slope gradient (Fig. 4b).

Soil bulk density was influenced by position, slope gradient and depth after 20 mule passes (Table 1). Position, depth, and interaction between position and depth were all significant variables (p<0.05). Significant interaction terms were position and depth (p<0.05).

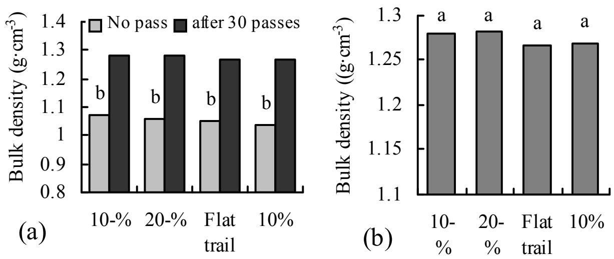

Fig. 4 Average of the bulk density in g·cm^{-3} after mule logging method by trail slope gradient (a) and by independent samples t-test and Duncan's test (b) after logging. Mean values followed by the same letter are not statistically different by Duncan's test.

Table 1. Analysis of variance (ANOVA) for the effect of slope gradient, sample point and depth on bulk density at 0–10 cm soil depth

Source	SS	*df*	MS	F	*p*
SLOPE	0.003	3	0.001	1.4	0.25
CT	0.075	1	0.075	102	0
DEPTH	0.685	2	0.342	463.2	0
SLOPE * CT	0.002	3	0.001	0.949	0.42
SLOPE * DEPTH	0.005	6	0.001	1.203	0.32
CT * DEPTH	0.108	2	0.054	73	0
SLOPE * CT * DEPTH	0.002	6	0	0.481	0.82

On flat trail at 0–10 cm depth, soil bulk density increased 14.3% from 1.05 to 1.2 g·cm^{-3}. Increases at depths of 10–20 cm and 20–30 cm were negligible. On declining mule hauling trails (slope -20%), soil bulk density in the surface layer (0–10 cm) had the highest increase from 1.06 to 1.27 g·cm^{-3} (20%). On trails with slopes of 10% and -10%, increases in bulk density in the surface layer were not significantly different (16%). Trail slope gradient had no significant effect on soil bulk density, although declining trails had higher bulk densities than inclining trails. The greatest increase in soil bulk density was observed at 0–10 cm soil depths and, with increasing depth, soil bulk density did not vary between the four slopes classes (Fig. 5b). Bulk density at 10–20 cm and 20–30 cm depths did not vary between control and compacted samples Fig. 5a).

Discussion

The results showed that the mule logging operation had not severe damages to the residual stand. Of seedlings/saplings along the mule paths, 22% were damaged. Note that in this method of transporting the wood, there was no damage to standing trees based on the sampling in the study area. Of the damaged seedlings/saplings, 80.4% were seedlings, 14.2% were small saplings,

and 5.4% were saplings. The findings of this study are consistent with results of other researchers (Dykstra and Heinrich 1996; Wang 1997; Shrestha 2002; Ghaffariyan et al. 2009).

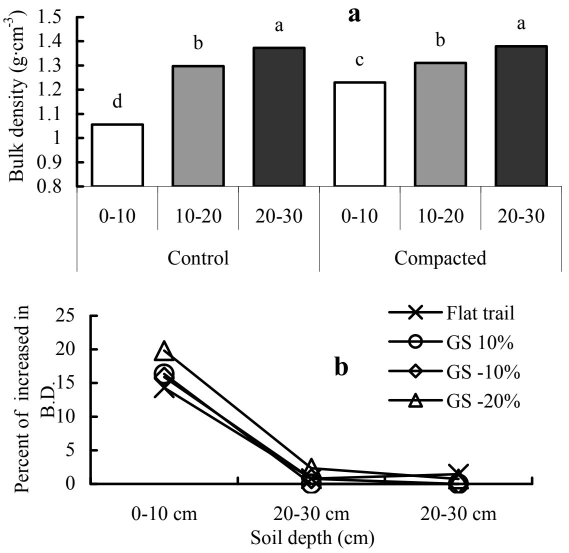

Fig. 5 Bulk density by soil depth on control and compacted sites (a), and average bulk density by slope gradient and soil depth after traffic (b). Mean values followed by the same letter are not statistically different by Duncan's test.

The soil compaction survey was quick and easy to complete. The mule trail pattern was unevenly distributed because of terrain steepness and this situation might bias this results. The degree and severity of the soil disturbance is superficial in agreement with others' results (Thompson and Sturos 1984; Wang 1997; Shrestha et al. 2008).

Soil bulk density increased significantly after mule hauling. This observation is consistent with results of other research (Jamshidi et al. 2008; Shrestha et al. 2008). Increased bulk density at 10–20 cm and 20–30 cm depths was not observed, possibly due to the relatively light weight of the draught animals and resulting low pressure on the soil at these depths. Damage to seedlings/saplings might have been avoided through the application of more careful logging procedures and applying low impact logging methods such as preplanning of skid trails.

Conclusions

Soil bulk density increased only in the 0–10 cm soil layer. Based on the results of this study, we can conclude that the mule logging operation had not drastic damages to the residual stand and regeneration. Hence, this small-scale logging system can be first preference among skidding alternatives in the steep terrain conditions. The results of evaluation test or practices indicated that this timber extracting technique is feasible, applicable and reasonable in small tree harvesting with a low impact to forest environment. Therefore, the advantages of mule logging can be considered as small-scale logging method in the Hyrcanian forest because of the low damage to residual stands and seedling and low impact to soil. About 40% of the Hyrcanian Forests are located in mountainous areas inaccessible to mechanical logging equipment where cable yarding technologies are undeveloped. Therefore, the mule logging can provide a solution to accessibility in this mountainous terrain.

References

Akay AE. 2005. Determining Cost and Productivity of Using Animals in Forest Harvesting Operations. *Journal of Applied Sciences Research*, **1**(2): 190–195.

Dykstra DP, Heinrich R. 1996. FAO model code of forest harvesting practice. Rome: FAO, pp. 97.

Ghaffariyan MR, Durston T, Sobhani H, Marvi Mohadjer MR. 2009. Mule logging in Northern Forests of Iran: a study of productivity, cost and damage to soil and seedlings. *Croatian Journal of Forest Engineering*, **30**(1): 67–75.

Ghaffariyan MR. 2002. Investigation of production and stand damage of mule logging in Kheyrudkenar forest. M.Sc. thesis. Natural Resources Faculty. Tehran: University of Tehran.

Heinrich R. 1985. Medium technology in wood harvesting. Logging and transport in steep terrain. Rome: FAO, pp. 46.

Jamshidi R, Jaeger D, Raafatnia N, Tabari M. 2008. Influence of two ground-based skidding systems on soil compaction under different slope and gradient conditions. *Journal of Forest Engineering*, **19**(1): 9–16.

Jourgholami M, Majnounian B, Zobeiri M, Feghhi J. 2008. Evaluation of production and costs of mule logging in down and up slopes (case study: Kheyrud forest). *Iranian Journal of Natural Resources*, **61**(3): 625–636.

McGonagli K. 1979. Southern horse and mule logging in Alabama. Logging system guide. US Forest Service.

Oskarshamn BP. 1983. Extraction using draught animals. Technical field note 3. Swedish Forestry Technique with Possible Applications in the Third World. Stockholm.

Rodriguez EO, Fellow AM. 1986. Wood extraction with oxen and agricultural tractors. FAO Forestry Paper No. 49. Rome.

Sessions J, Boston K, Murphy G, Wing MG, Kellogg L, Pilkerton S, Zweede JC, Heinrich R. 2007. *Harvesting operation in the Tropics*. Berlin: Springer-Verlag.

Shrestha SP. 2002. Opportunities and limitation of animal logging in the US South. PhD. Theses. Auburn, Alabama: Auburn University, p. 194.

Shrestha SP, Lanford BL, Rummer R, Dubois M. 2008. Soil Disturbances from Horse/Mule Logging Operations Coupled with Machines in the Southern United States. *Journal of Forest Engineering*, **19**(1): 17–24.

Thompson MA, Sturos JA. 1984. Bunching with low-investment systems in northern hardwood pole thinning, American Society of Agricultural Engineers, Paper No. 84-1599, p. 32.

Toms CW, Dubois MR, Bliss JC, Wilhait JH, Rummer RB. 2001. A survey of animal-powered logging in Alabama. *Southern Journal of Applied Forestry*, **25**(1): 17–24.

Wackerman AE, Hasgestein WD, Michell AS. 1966. Harvesting Timber Crops. New York: McGraw-Hill.

Wang LH. 1997. Assessment of animal skidding and ground machine skidding under mountain condition. *Journal of Forest Engineering*, **8**(2): 57–64.

Wang LH. 1999. Environmentally Sound Timber Extracting Techniques for small tree Harvesting, Presentation at the 1999 ASAE Annual International Meeting Sponsored by ASAE, Toronto, Canada. p. 7.